CONCLUSIONS

1. Our target dosage of 150 lb of N per acre as a 32-percent N solution without an effective surfactant was probably close to the maximum safe dosage for the weather and tree conditions. Only 4 percent of the trees had as much as 30 percent of their foliage surface injured on the plot receiving 123 lb of N per acre.

2. The incidence of terminal or leader injury was not increased by foliar or soil fertilization.

3. Neither foliar- nor soil-applied N had any measurable effect on height growth during the first 4 years after treatment.

4. Assumptions had to be made about the amount of foliar-applied nitrogen. Although target dosage was 150 lb N per acre, the measured dosage averaged 96 lb.

5. Nitrogen fertilization increased growth in this recently thinned stand by 22 ft^3 per year or 88 ft^3 during the 4-year period. This 35-percent improvement in growth was about the same for both soil and foliar applications despite the likelihood that much less N was applied in the foliar application.

6. Foliar fertilization decreased cone production in the second growing season after treatment and urea prill increased cone production in the fourth growing season by 2.5 fold.

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Metric Conversion Factors

1 pound/acre	= 1.121 kilograms/hectare
1 acre	= 0.405 hectare
1 foot	= 0.3048 meter
1 inch	= 2.54 centimeters
1 ft^2/acre	= 0.2296 m^2/ha
1 ft^3/acre	= 0.06997 m^2/ha
1 tree/acre	= 2.47 trees/ha
1 mile	= 1.61 kilometers

PNW-329 March 1979

EFFECTS OF SOIL AND FOLIAR APPLICATIONS OF NITROGEN FERTILIZERS ON A 20-YEAR-OLD DOUGLAS-FIR STAND

by

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ABSTRACT

We compared growth and cone production of Douglas-fir treated 4 years earlier with 150 pounds N per acre applied as urea prill by hand and as a 32-percent N solution applied by helicopter. Nitrogen fertilization increased growth by 88 ft^3 per acre during the 4 years after treatment; this 35-percent gain was similar for both soil (prill) and foliar (solution) applications. Although cone production on the prill-treated plots averaged twofold to fourfold greater than on the control plots, these differences were not statistically significant.

KEYWORDS: Nitrogen fertilizer response, fertilizer applications, cone production, Douglas-fir, *Pseudotsuga menziesii*.

INTRODUCTION

Although application of urea to the soil is the most common method of fertilizing Douglas-fir forests in the Pacific Northwest, application of concentrated N solutions to the foliage is an alternative method (Miller and Young 1976). Concentrated salt solutions are more likely to damage foliage or shoots and thus reduce the beneficial effects of fertilization or even reduce growth below that of unfertilized trees. Moreover, fertilizing Douglas-fir forests with a 32-percent N solution applied as a foliar spray has been more expensive than fertilizing with urea prill. For example, in large-scale operations, total costs per pound of N applied as a 32-percent N solution averaged 21 percent more than for urea fertilization (Miller and Young 1976).

We report the 4-year results of a field trial comparing the effects of soil and foliar application in a recently thinned, 20-year-old stand of Douglas-fir. We wanted to answer the following questions: To what extent can growth in height and total cubic volume and production of cones be increased by application of 150 lb of N per acre as urea prill and as concentrated urea-ammonium nitrate solution (32-percent N)?

MATERIALS AND METHODS

Study Area

The study area lies 7 miles southeast of Canyonville, Oregon, on a northeast aspect (fig. 1). Elevation of the nine 0.2-acre plots in the study area ranges between 2,500 and 2,850 ft; slopes range between 20 and 45 percent. Annual precipitation at Riddle, which is located about 14 miles to the northwest, averages 36.6 in with 6.0 in falling from April 1 through September 30.[1]

[1]Unpublished data filed at the Douglas County Water Master's Office, Roseburg, Oregon.

Soils in the study area are well-drained and are developing from a highly fractured metamorphic shale. Eight of the nine plots are located on the McGinnis series (Typic Haploxerult, clayey-skeletal, mixed, mesic). This soil has a dark brown, clay loam surface with a red, gravelly clay subsoil. The McGinnis soil is less than 40 in deep and contains 35 to 50 percent of highly weathered shale fragments. Site index among the eight plots in this soil series averaged 112 and ranged between 103 and 116 ft (100-year index age).

The remaining plot is on the Pollard series (Typic Haploxerult clayey, mixed, mesic) which is deeper and more productive. Although the surface soil is also dark brown and clay loam in texture, the subsoil is red clay with less than 20 percent of shale fragments. This soil is deeper than 40 in and has more water-holding capacity than McGinnis soils. Site index on plot 10 was 140.

The Stand

Our 20-year-old stand originated after a seed tree cut and broadcast burning in 1951. Prior to precommercial thinning in August and September 1972, the young stand contained 340 to 880 Douglas-fir per acre that were 1.6-in d.b.h. and larger; these Douglas-fir represented 88 to 100 percent of the total basal area (table 1). Madrone was initially present in all but one plot; chinkapin, red alder, and willow were present on some plots. The thinning removed 32 to 68 percent of the initial basal area of Douglas-fir and reduced density to 140 to 225 Douglas-fir stems and 0 to 85 hardwood stems per acre (table 1); all residual Douglas-fir were less than 8-in d.b.h. (table 2). The three plots sampling each treatment spanned the range of the initial and final stand conditions (table 1).

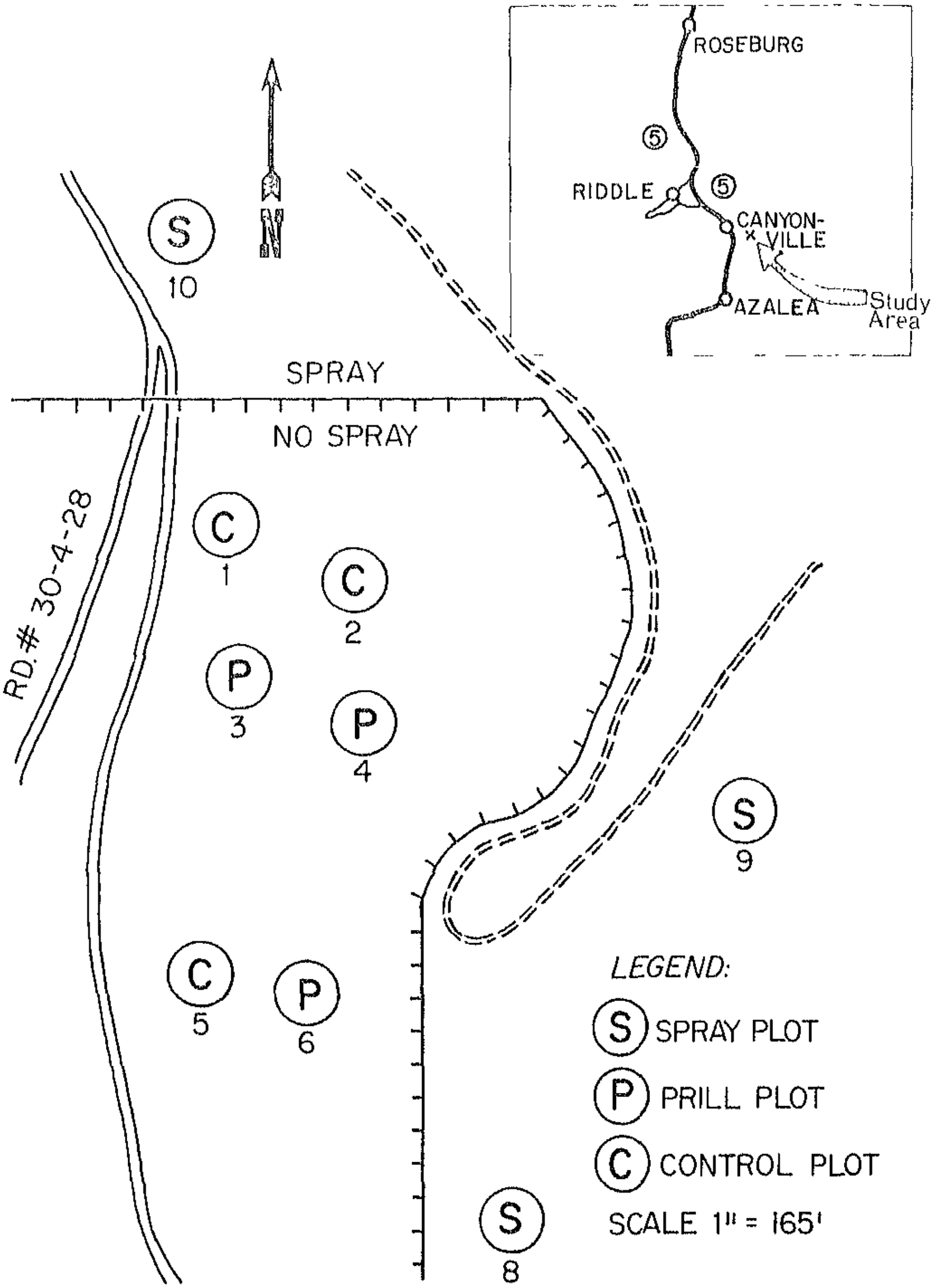

Figure 1.--Vicinity and schematic map at the study area.

Table 1--Stand statistics before and after thinning, per acre basis[1]

Fertilizer status	Plot No.		Douglas-fir D.b.h.	Douglas-fir Stems	Douglas-fir Basal area	Hardwoods[2] D.b.h.	Hardwoods[2] Stems	Hardwoods[2] Basal area
			Inches	Number	Square feet	Inches	Number	Square feet
None	2	Before		340	19.2		45	1.8
		After	4.0	150	13.0	2.8	35	1.6
	1	Before		590	26.9		45	1.0
		After	3.7	180	13.5	2.0	45	1.0
	5	Before		790	41.3		0	0
		After	4.1	225	20.8	--	0	0
Prill	6	Before		500	24.8		105	2.8
		After	3.8	160	12.4	2.3	95	2.2
	4	Before		585	28.7		20	.5
		After	4.2	160	15.3	2.1	20	.5
	3	Before		880	40.7		10	.3
		After	3.9	180	14.8	2.4	10	.3
Spray	8	Before		555	22.4		65	1.9
		After	3.2	140	7.8	2.2	50	1.3
	10	Before		765	45.5		235	6.0
		After	4.4	180	18.5	2.2	50	1.2
	9	Before		805	25.0		80	4.4
		After	3.4	180	11.1	1.9	20	.4

[1] Plots are arrayed within treatment by increasing number of Douglas-fir in the original stand.

[2] Includes madrone on all but one plot; chinkapin and incense-cedar on some plots.

Table 2--Diameter distribution of residual Douglas-fir, per acre basis

Fertilizer	D.b.h. class, inches: 2	3	4	5	6	7	All
			Average number of trees				
None	30	42	70	33	7	3	185
Prill	25	45	52	32	13	0	167
Spray	33	58	45	23	5	1	167
			Average cumulative percent				
None	100	84	61	23	5	2	
Prill	100	85	58	27	8	0	
Spray	100	80	46	19	5	2	

Plot Installation and Tree Measurement

We established nine 0.2-acre, circular plots in this stand before the 1973 growing season. We located three plots in an area designated for foliar fertilization by helicopter. We placed the remaining six in an abutting 14-acre, non-spray area and randomly selected three of these plots for hand fertilization with urea prill; the other three were control plots (fig. 1). Thus, our spray-treated plots were adjacent, but not randomly intermingled with the other plots.

We measured diameters of all trees 1.6 inches and larger and heights of 15 trees per plot at 2-year intervals; two-thirds of these 15 height trees initially exceeded the quadratic mean d.b.h. of their respective plot. To reconstruct information about the stand before thinning, we determined species, number, and d.o.b. of all stumps exceeding 1.9 in. We estimated d.b.h. of these cut trees by using regression equations of d.b.h. and stump d.o.b. for 8 to 18 live trees measured on each plot.

Statistical Analysis

The non-random location of the spray-treated plots theoretically precludes valid statistical analysis of the effects of foliar fertilization, because some effects of this treatment could be due to site or stand differences associated with the spray-treated plots being 300 to 400 ft away from the nearest control or prill-treated plots. We assume the treatments equally sampled a fairly homogeneous stand and therefore, think this theoretical confounding has little influence on our conclusions.

We tested differences among treatment means by either analysis of variance or by analysis of covariance when a suitable covariate was available. We separated significant differences among the three means by the orthogonal comparisons: control *versus* fertilized, and soil *versus* foliar fertilization. We used the 10-percent probability level ($P<0.10$) to judge differences as real or statistically significant.

Fertilization

Urea prill.--Our original plan was to apply both fertilizers prior to the 1973 growing season; however, the foliar application by helicopter was inadvertently delayed. On March 24, 1973, when the Douglas-fir buds were still tight, we fertilized plots 3, 4, and 6 with 150 lb N per acre using agricultural grade prill. We uniformly broadcast the prill by hand within 0.4-acre circular areas concentric with the 0.2-acre measurement plots. Volatilization losses were unlikely, because the soil was moisture saturated at fertilization and rain fell the next day; the weather station at Riddle reported 0.72 in of precipitation in the 7 days after fertilization.

Foliar spray.--After an unplanned delay until June 9, we applied a commercial, 32-percent N solution by helicopter over the 55-acre spray area. Diameter growth had started and buds had burst; most trees had completed 10 to 25 percent of their twig growth.

Our target dosage was 150 lb of N per acre. To enhance spreading of the solution over the foliage, we added 0.5 weight percent of "Plyac", a commercial spreader-sticker.[2] Subsequently, we found that this surfactant was ineffective, because it coagulates rather than disperses in this concentrated salt solution. We surmise that the ineffectiveness of this surfactant had little impact on our results.

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[2]The use of trade, firm, or corporation names in this publication is for the information and convenience of the reader. Such use does not constitute an official endorsement or approval by the U.S. Department of Agriculture of any product or service to the exclusion of others that may be suitable.

We controlled and measured the distribution of the foliar spray. To insure accurate flight lines, we marked the boundaries of the spray area with yellow flagging, aluminum foil, and helium-filled balloons. To sample the actual dosage on each spray plot and the amount of drift to prill-treated and control plots, we placed 1-ft-square sampling papers near 10 randomly selected trees per plot. We fixed these papers on boards either placed atop a pole raised to tree height or on the ground in a nearby opening (fig. 2). In the three spray-treated plots, we used five raised targets and five on the ground. On the six other plots within the non-spray area, we used three raised targets and seven on the ground. We collected these paper targets after fertilization and stored them in an iced container before analysis for nitrogen contents.[3]

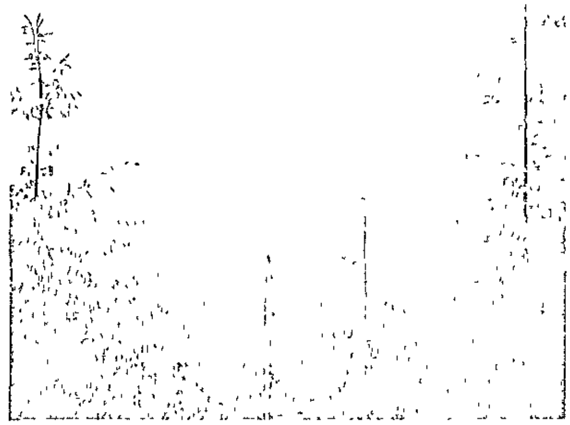

Figure 2.--Spray dosage at canopy level was measured on elevated sampling papers. Note also the extent of twig extension when the liquid fertilizer was applied.

RESULTS AND DISCUSSION

Measured Spray Dosage

Average N dosages measured on the three helicopter-treated plots varied widely and were consistently less than the prescribed 150 lb of N per acre. Average N dosages and their 95-percent confidence limits on the sprayed plots were 64±8, 100±13, and 123±22 lb per acre. Dosage on individual sampling papers ranged between 52 and 165 lb of N per acre.

Drift onto the remaining six plots within the non-spray area was minimal and the average N dosages and 95-percent confidence limits for individual plots ranged between 0±0 and 3.5±1.2 lb per acre. Maximum dosage on any paper in the non-spray area was 5.9 lb N per acre, even though some sample papers were within 300 ft of the spray-treated plots.

Our measured dosage estimates the actual dosage received by the trees. This dosage for each spray-treated plot was consistently less than our target dosage of 150 lb N per acre. We offer two explanations. First, some decrease in dosage may be characteristic of helicopter applications of nitrogen solutions. For example, small droplets of spray could be lost to the atmosphere. If so, then one would have to increase a desired dosage to compensate for assumed losses. Second, fewer than 150 lb N per acre could have been released from the helicopter, presumably because the pilot avoided the spray/non-spray boundary to minimize drift into the non-spray area. By monitoring spray dosage, however, we were reasonably assured that growth on the control and prill-treated plots was negligibly affected by the spray fertilization and that the spray-treated plots received less nitrogen per acre than did the prill-treated plots.

Spray Injury

To foliage.--Visual estimates after the first growing season showed that as average dosage per plot increased, more of the trees had injured

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[3]Nitrate-N analyses of these sampling papers were kindly provided by Dr. Donald C. Young, Research Chemist, Union Oil Co., Brea, Calif. Total N was computed on the basis of the percentage of nitrate in the fertilizer.

needles and a larger percentage of the needles on these trees were injured (table 3). On plot 8, which received an average of 123 lb of nitrogen per acre, 93 percent of the Douglas-fir had some needle injury, however, only 4 percent of the trees had as much as 30 percent of their foliage surface injured. In this heavily thinned stand, severity of foliar burning was not related to crown class (table 3). The combined data from all spray plots showed that 56 percent of the trees had 10 to 20 percent of their needle surface burned, but only 1 percent of the trees had 30 or more percent burned. We observed more severe crown burning in other portions of the sprayed area which probably received heavier dosages of spray, e.g., near the edge of the stand where the helicopter pivoted to change direction.

According to previous investigations, negative effects of injury to Douglas-fir foliage began to offset benefits of fertilizing when more than 30 percent of the needle surface of a tree was injured (Miller and Young 1976). Assuming the ineffective surfactant had little influence on spray injury, we concluded that our target dosage of 150 lb of N per acre was probably close to the maximum safe dosage for the weather and tree conditions at time of treatment.

To leaders.--After the first growing season, 10 percent of the trees on the sprayed plots had curled or dead leaders compared to 8 percent broken or dead leaders on the prill-treated and 18 percent on control plots. These differences were not statistically different and indicate the ferti-

Table 3--Injury to Douglas-fir foliage after spray application of a 32-percent N solution

N per acre	Crown class	Number per acre	Injury class[1]			
			0	10	20	30
Pounds			- - - - Percent of trees - - - -			
64	Dominant	125	68	28	4	0
	Codominant	50	60	40	0	0
	Intermediate	5	100	0	0	0
	All	180	67	31	3	0
100	Dominant	115	48	52	0	0
	Codominant	60	50	33	17	0
	Intermediate	5	0	100	0	0
	All	180	47	47	6	0
123	Dominant	85	0	76	24	0
	Codominant	55	18	55	18	9
	Intermediate	0	--	--	--	--
	All	140	7	68	21	4
[2]96	All	167	43	47	9	1

[1]The estimated percent of needle surface on the tree that appeared discolored or burned.

[2]Average of the three spray plots.

lizer treatments did not increase the incidence of misformed leaders.

Height Growth

Annual height growth in nearly all plots during the 4 years after treatment averaged about 10 percent less than that during the 2 years before treatment (table 4). Although this reduction probably indicates that the rate of height growth peaked prior to treatment, it could show that heavy thinning temporarily reduced height growth as previously observed in low-site quality Douglas-fir (Staebler 1956, Miller and Reukema 1976).

Although average height growth on fertilized plots was slightly greater than control growth, this difference was not significantly different ($P<0.38$) after adjustment for the greater height growth on the fertilized plots prior to treatment. Therefore, contrary to our expectations, neither soil- nor foliar-applied nitrogen had any measurable effect on height growth.

Cubic Volume Growth

Volume growth on individual plots during the subsequent 4-year period was closely related to growing stock after thinning (fig. 3). We reduced the effects of these initial differences in growing stock by using covariance analysis to adjust average growth for each treatment to a common starting volume.

This adjusted volume growth on the prill-treated plots exceeded that on the control plots by 37 percent or 92 ft^3 during the 4-year period (table 5). Likewise, the adjusted volume growth of the spray-treated plots averaged 80 ft^3 more than that of the unfertilized plots for the 4-year period or 12 ft^3 less than that of the prill-treated plots. Orthogonal comparisons indicated a signifi-

Table 4--Average initial height and annual height growth before and after fertilization

Fertilizer	N per acre	Plot[1]	Initial height	Annual height growth 1971-72	Annual height growth 1973-76	Ratio 1973-76 / 1971-72
	Pounds		- - - - - - Feet - - - - - - -			
None	0	2	26.8	2.4	2.2	0.91
	0	1	29.1	2 5	1.9	.75
	0	5	31.3	2.4	2.2	.96
	0	Average	29.1	2.4	2.1	.90
Prill	150	6	29.0	2.4	2 4	1.00
	150	4	29.2	2.8	2.6	.93
	150	5	31.0	2.8	2.3	.85
	150	Average	29.7	2.7	2.4	93
Spray	123	[2]8	24.6	2.3	2 2	.93
	100	[2]10	33.8	2.9	2.7	.94
	64	9	26.3	2.4	1.9	.78
	96	Average	28.2	2.5	2.3	.88

[1]Plots are arrayed within treatment by increasing number of Douglas-fir in the original stand.

[2]Pollard soil series. The other plots are on the McGinnis series.

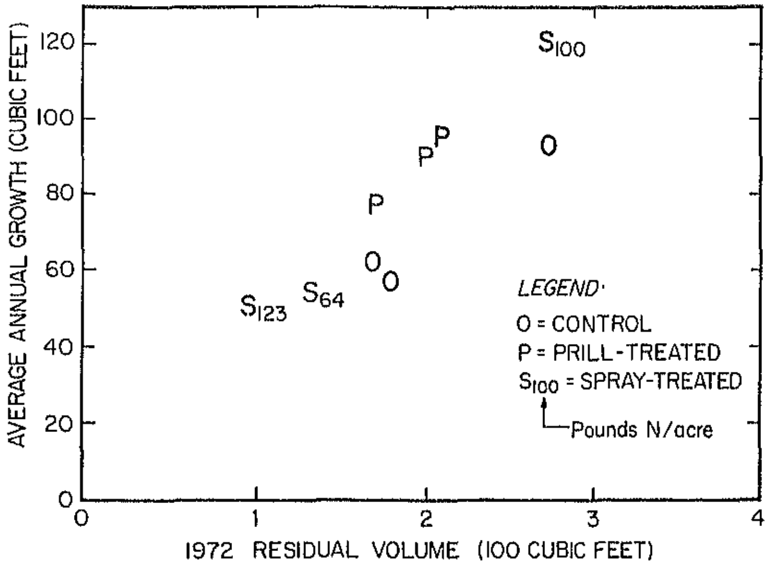

Figure 3.--Average annual gross volume growth during 4 years after treatment, all species, trees 1.6 in and larger, per acre basis.

cant difference between the fertilized plots and the control plots (P<0.01), but no significant difference between the prill and the spray-treated plots (P<0.58). Acknowledging the non-random allocation of the spray plots, we speculate that the response to foliar spray was comparable to that of prill.

One could argue that to compare the effectiveness of soil and foliar application, we should adjust volume response to foliar fertilization for the shorter period of time after treatment (3.9 to 3.75 versus 4.0 growing seasons) and for the lower N dosage evidently received on the spray-treated plots (96 versus 150 lb N per acre). Although such adjustments are logical, estimating their magnitude is speculative. For example, we don't know how closely our measured N dosage corresponds to the dosage actually released by the helicopter. If we assume (1) the helicopter sprayed an average of 96 lb of N per acre, and (2) a linear response surface between 0 and 150 lb of N per acre, then average growth on the spray-treated plots would be increased by 56 percent. Although we considered both assumptions reasonable, we chose the conservative approach: we assumed that 150 lb of N per acre were applied by the helicopter to the spray-treated plots

Table 5--Average initial volume and gross volume growth of all trees 1.6 in d.b.h. and larger, per acre basis

Fertilizer	N per acre	Volume after thinning	Periodic annual growth		4-year gain[1]	
			Unadjusted	Adjusted[1]	Absolute	Relative
	Pounds	Cubic feet				Percent
None	0	204	69	62	--	--
Prill	150	190	86	85	92	37
Spray	96	166	74	82	80	32

[1]Growth adjusted for initial differences in stand volume.

and concluded that fertilizer efficiency of both methods of supplying nitrogen was comparable during the first 4 years after treatment.

Longer-term measurement at this and other study areas[4] will provide more definitive comparisons of these two methods of fertilization. We know that application of concentrated nitrogen solutions requires reduced N dosage and more uniform distribution than does application of urea prill, because growth after foliar fertilization more strongly reflects the net effect of fertilizing, i.e., improved nutritional status minus negative effects of chemical burning. If, for example, spray dosages on our plots had greatly exceeded our highest dosage of 123 lb of N per acre, foliar or terminal damage may have been increased and volume response been reduced. The N dosage that can be applied to Douglas-fir stands without causing excessive needle damage depends on numerous factors including N source, additives, season of year, stage of tree growth, spray volume relative to amount of foliage, and uniformity of spray application (Miller and Young 1976). We believe that in most Douglas-fir stands, however, dosage of at least 100 lb N per acre can be applied with little concern for foliage injury.

[4]Unpublished data on file at the Forestry Sciences Laboratory, Olympia, Washington.

Cone Production

We were interested in cone production for at least two reasons: (1) to know if commercial fertilizers increased cone production and (2) to learn if increased cone production could have reduced gains in volume production.

In the second and fourth growing seasons after fertilization of our 20-year-old stand, cone production by 15 sample trees per plot was highest in prill-treated plots, much lower in the control plots, and lowest in the spray-treated plots (table 6). Method

Table 6--Cone production in the 2d and 4th years after treatment, 15 trees per plot

Fertilizer	N per acre	Plot	Trees with cones		Cones per tree[1]	
			1974	1976	1974	1976
	Pounds					
None	0	2	2.0	5.0	8.7	9.9
	0	1	0	1.0	0	.5
	0	5	1.0	7.0	.3	3.3
		Average	1.0	4.3	3.0	4.6
Prill	150	6	5.0	6.0	8.5	11.5
	150	4	6.0	9.0	34.3	11.3
	150	3	3.0	9.0	3.3	13.1
		Average	4.7	8.0	15.4	12.0
Spray	123	8	0	4.0	0	5.0
	100	10	0	3.0	0	1.3
	64	9	0	2.0	0	.9
		Average	0	3.0	0	2.4

[1]Equals total cones ÷ 15 sample trees.

of fertilization influenced the number of trees that bore cones as well as the average number of cones per sample tree (total cones ÷ 15 trees). In the second growing season, foliar fertilization clearly reduced cone production. Our orthogonal comparisons could not compare cone production on prill-treated and control plots. A separate test of these treatment means, however, showed that urea prill significantly increased the number of trees with cones ($P<0.02$). The total cones per plot (or average number of cones per tree), however, was not significantly different from that on the control plots ($P<0.28$), despite an apparent fivefold increase in production.

In the fourth growing season, cone production on the spray-treated plots increased, but remained less than that on the control plots. Cone production did not differ significantly between the control and all fertilized plots ($P<0.30$), however, cone production on the prill-treated plots was more than fivefold greater than on the spray-treated plots, ($P<0.02$) and 2.5 fold greater than on the control plots ($P<0.06$).

These results indicate that the large increases in cone production in the 2d and 4th years after fertilization with urea prill was probably a true effect in the 4th year. Moreover, the absence of cone production in the second growing season after foliar fertilization was also an effect of that treatment.

To determine if diameter growth of prill-fertilized trees was depressed by increased cone production, we regressed basal area growth and cone production of individual trees. The absence of a significant slope to the regression line for each of the prill-treated plots indicated that these levels of increased cone production had no measurement effect on diameter and probably on volume growth.

Others[5] have reported that N fertilization of Douglas-fir near time of bud burst increased cone production in the following year (Stoate et al. 1961, Ebell and McMullan 1970). Timing of fertilization is generally considered critical to its effectiveness. For example, Stoate et al. (1961) reported that fertilization 2 weeks before or after bud burst did not stimulate cone production. Since our application of urea prill was at least 4 weeks before bud burst and that of N solution was several weeks after bud burst, both methods might have been more effective if applied closer to bud burst.

Although fertilization is a commonly used means for inducing cone crops in conifers (Puritch 1972), fertilization has been relatively ineffective in years of cone failure (Steinbrenner et al. 1960). Regional cone production was generally poor in 1974 and 1976 when we observed our trees, so our observed differences between fertilized and control trees may have been reduced.

Ebell and McMullan (1970) demonstrated that the nitrate form of nitrogen is more effective than the ammonium form for producing cones in Douglas-fir. Thus, our urea-ammonium nitrate solution should have been more effective than urea prill. We could not test this, because our application of the nitrate-containing fertilizer solution was made after twig growth was 10 to 25 percent completed. Application after bud burst, coupled with the likelihood that the solution could have damaged bud tissue in the expanding twigs, may explain the absence of cone production in the year following foliar fertilization.

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[5]Ebell, L. F. 1962. Growth and cone production responses of Douglas-fir to chemical fertilization. Report on Project B.C. 1, Can. Dep. For. B.C. District, 41 p. Victoria, B.C. Mimeo.

CONCLUSIONS

1. Our target dosage of 150 lb of N per acre as a 32-percent N solution without an effective surfactant was probably close to the maximum safe dosage for the weather and tree conditions. Only 4 percent of the trees had as much as 30 percent of their foliage surface injured on the plot receiving 123 lb of N per acre.

2. The incidence of terminal or leader injury was not increased by foliar or soil fertilization.

3. Neither foliar- nor soil-applied N had any measurable effect on height growth during the first 4 years after treatment.

4. Assumptions had to be made about the amount of foliar-applied nitrogen. Although target dosage was 150 lb N per acre, the measured dosage averaged 96 lb.

5. Nitrogen fertilization increased growth in this recently thinned stand by 22 ft^3 per year or 88 ft^3 during the 4-year period. This 35-percent improvement in growth was about the same for both soil and foliar applications despite the likelihood that much less N was applied in the foliar application.

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Metric Conversion Factors

1 pound/acre	= 1.121 kilograms/hectare
1 acre	= 0.405 hectare
1 foot	= 0.3048 meter
1 inch	= 2.54 centimeters
1 ft^2/acre	= 0.2296 m^2/ha
1 ft^3/acre	= 0.06997 m^2/ha
1 tree/acre	= 2.47 trees/ha
1 mile	= 1.61 kilometers

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EFFECTS OF SOIL AND FOLIAR APPLICATIONS OF NITROGEN FERTILIZERS ON A 20-YEAR-OLD DOUGLAS-FIR STAND

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ABSTRACT

We compared growth and cone production of Douglas-fir treated 4 years earlier with 150 pounds N per acre applied as urea prill by hand and as a 32-percent N solution applied by helicopter. Nitrogen fertilization increased growth by 88 ft^3 per acre during the 4 years after treatment; this 35-percent gain was similar for both soil (prill) and foliar (solution) applications. Although cone production on the prill-treated plots averaged twofold to fourfold greater than on the control plots, these differences were not statistically significant.

KEYWORDS: Nitrogen fertilizer response, fertilizer applications, cone production, Douglas-fir, *Pseudotsuga menziesii*.